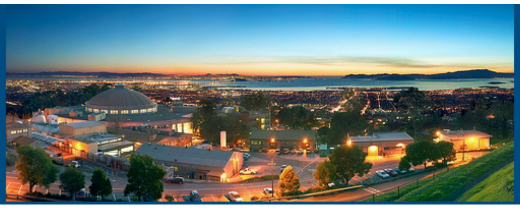


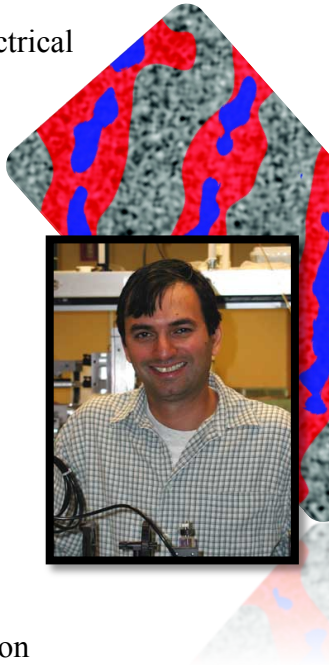
DOE Offices of Basic Energy Sciences and Energy Efficiency and Renewable Energy Collaborate to Develop Nanostructured Electrolytes for Lithium Batteries

LBNL work under the direction of Nitash Balsara of the Materials Sciences and Environmental Energy Technologies Divisions has led to the development of a new electrolyte for lithium ion batteries which has the potential to double their energy densities. Funding from the DOE Office of Energy Efficiency and Renewable Energy through LBNL's Batteries for Advanced Transportation Technologies (BATT) Program supported the synthesis of the new electrolyte while funding from The Office of Basic Energy Sciences (BES) supported research to establish the mechanism by which performance is improved. The technology has been licensed by a startup company Seeo, Inc., which is continuing work on the building and testing of batteries using the new LBNL electrolyte. LBNL and Seeo were jointly awarded an R&D 100 Award in 2008 for this work.

> The prototype solid electrolyte lithium batteries provide a two-fold increase in energy density.

Currently produced lithium-ion batteries use a flammable organic liquid electrolyte between the anode and cathode. Replacing the liquid with a solid electrolyte has the potential for not only increased safety but also for improving energy density–two improvements required for the widespread use of lithium-ion batteries in electric vehicle applications.

The novel approach taken by the BATT program was to develop solid electrolytes based on nanostructured block copolymers. Prior work had shown that although the increased stiffness of a solid electrolyte resists the formation of crystaline growths (dendrites) on the Li, which can short-circuit the battery, it also reduces ionic conductivity, which leads to poorer electrical performance. However, Balsara showed that when solid electrolytes derived from block copolymers are used, the ionic conductivity of the electrolyte increases with increasing stiffness, which enables optimization of both electrical and mechanical properties of the electrolyte.



Work performed in the LBNL Soft Matter Microscopy Program (BES) uncovered the fundamental reasons for these unexpected properties of block copolymer electrolytes. High resultion energy-filtered transmission electron microscopy (TEM) developed at the LBNL National Center for Electron Microscopy especially for light atom detection was used to map the location of the lithium in the electrolytes. It showed that the lithium was increasingly sequestered in the middle of nanostructured channels in the electrolyte as the polymer molecular weight was increased to increase the stiffness. It is believed that the ion conductivity occurs efficiently in these channels while the stiff channel walls resist dendrite formation.

Seeo, Inc. is is now developing a solid-state rechargeable Li-metal battery based on the LBNL work. In a battery with a lithium metal anode, and no other changes to system chemistry, use of the prototype solid electrolyte should provide a two-fold increase in energy density. Moreover, the new batteries will be far more stable, because the solid electrolyte acts as a continuous physical barrier between a battery's reactive electrodes, inhibiting short circuits that can lead to thermal runaway and explosion.

N. Balsara (510 642-8973), Materials Sciences Division (510) 486-4755, Berkeley Lab.

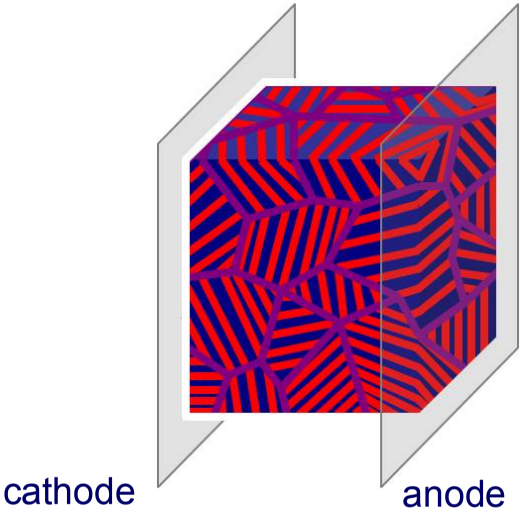
BES publication

Gomez ED, Panday A, Feng EH, Chen V, Stone GM, Minor AM, Kisielowski C, Downing KH, Borodin O, Smith GD, Balsara NP. Effect of ion distribution on conductivity of block copolymer electrolytes. Nano Lett. 2009 Mar;9(3):1212-6.

EERE publication

Singh, M. Odusanya, O., Wilmes, Gregg., Eitouni, H., Gomez, E., Patel, A., Chen, V., Park, M., Fragouli, P., Iatrou, H., Hadjichristidis, N., Cookson, D., and Balsara, N. 2007. Effect of Weight on the Mechanical and Electrical Properties of Block Copolymer Electrolytes. Macromolecules 40: 4578—4585.

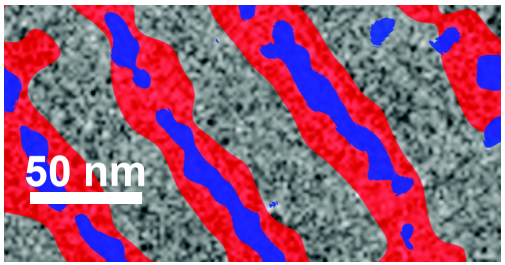
BES and EERE Collaborate to Develop Nanostructured Electrolytes for Lithium Batteries



EERE Project

New nanostructured block-polymer electrolytes were developed to replace the flamable liquid electrolyte currently used. The material, with soft conducting channels embedded in a hard insulating matrix, has the desirable feature of increasing the conductivity of the electrolyte while, at the same time, increasing the stiffness, and therefore safety, of the composite.

Micrograph of electrolyte



Conducting channels in red
Lithium ions in blue

BES Project

State-of-the-art microscopy techniques at LBNL's National Center for Electron Microscopy were used to image the position of Li ions in the electrolyte. Images showed that the Li was increasingly sequestered in the middle of nanostructured channels as the molecular weight (stiffness) of the polymer increased. Ionic conductivity increases in the channels and the stiff channel walls resist the damaging crystalline dendrite formation.

A patent based on work in both projects has been filed and licensed by startup company, Seeo, Inc.